Quantification of the relative efficiency of factory surveillance in the disclosure of tuberculosis lesions in attested Irish cattle

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In Ireland, factory surveillance of cattle for gross lesions is an important supplementary method for detecting herds infected with bovine tuberculosis (TB), and in recent years between 27 and 46 per cent of all new herd breakdowns in any year have been detected by this method. The aim of this study was to determine the relative efficiency of factories in detecting lesions among attested cattle slaughtered during 2003 and 2004. National databases were available on animal slaughter, programmes of tuberculin testing for bovine TB and laboratory confirmation of suspected lesions. Factories were ranked according to their submission risk (number of animals submitted with lesions/number of attested animals killed) and confirmation risk (number of animals with laboratory-confirmed lesions/number of animals submitted with lesions), adjusting for the risk profile of the animals slaughtered, including potential confounding factors such as their age and sex, whether they were purchased or homebred, the test history of their herd, the prevalence of bovine TB in the area and the season of slaughter. Approximately 3·7 million cattle were slaughtered in 42 Irish export-licensed factories during the two years. Complete data were available for 2,374,987 animals from 84,510 attested herds in 2845 District Electoral Divisions. Samples from 7398 animals with suspected TB lesions were submitted for laboratory examination; 4767 (64·4 per cent) were positive, 2011 were negative and 620 were inconclusive. The average unadjusted submission risk for all the factories was 22 per 10,000, ranging from 0 to 58 per 10,000. The unadjusted factory confirmation risk (excluding factories that had sent in fewer than 10 lesions) varied between 34·3 per cent and 86·3 per cent. The unadjusted and adjusted submission and confirmation risks were highly correlated, and animal-related factors (including their characteristics and origin) therefore did not contribute to the variations in factory-level submission and confirmation risks.

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BOVINE tuberculosis (TB), caused by the bacterium *Mycobacterium bovis*, is a chronic infectious disease affecting cattle, other animal species and human beings. A national eradication programme was initiated in Ireland in 1954 and initially made considerable progress, but further advancement has proved difficult. The programme consists of annual tuberculin skin testing of all cattle; reactors are removed and the herd is restricted from trade until all the animals test negative on two consecutive occasions two months apart (Good and others 2003). The detection at slaughter of gross lesions in attested cattle, that is, cattle from herds considered disease free on the basis of annual skin testing (factory surveillance), is an additional and important method for detecting infected herds as part of the programme. Between 1993 and 2001, between 27 and 46 per cent of all new herd breakdowns in any year were detected by factory surveillance (O'Keeffe and White 1999; T. Clegg, personal communication). Routine factory surveillance, conducted in Ireland by veterinarians employed as temporary veterinary inspectors, is based on the palpation, incision and inspection of a defined range of lymph nodes, including the parotid, mandibular, lateral and medial retropharyngeal nodes in the head, the cranial and medial tracheobronchial nodes, and the cranial, middle and caudal mediastinal nodes in the pleura. Because bovine TB lesions generally cannot be distinguished on gross inspection from non-tuberculous granulomas, suspect lesions from attested animals are further examined in the laboratory. In an earlier study, 66·1 per cent of lesions submitted from attested cattle were confirmed as bovine TB (Costello and others 1998).

There are complexities when quantifying the efficiency of factory surveillance because of the potential for major differences, in terms of bovine TB status, in the population of cattle being slaughtered at each factory. First, factors affecting the bovine TB status of animals at slaughter include the farm location (either the herd of origin or, if relevant, the location of the farm on which the animal was reared and/or finished), and the type and age of the animals. Secondly, after accounting for the bovine TB status of the slaughtered animals, other factors likely to affect the efficiency of surveillance include physical factors, such as line speed and light intensity, and human factors, such as the quality of inspection, as influenced by the competence of the inspector. Several preliminary studies have been made, some based on univariable analyses (de Kantor and others 1987, Corner and others 1990, Kobe and others 2000, Lenehan and others 2000) and one on a multivariable analysis (Martin and others 2003). The multivariable approach is preferable because it ensures that measures of efficiency are adjusted for the likely bovine TB status of the animals slaughtered at each factory. Martin and others (2003) detected a seven-fold difference between factories in the rate of disclosure of lesions among attested cattle at slaughter, after controlling for a limited range of potential confounding factors, including the month and year of slaughter, and the class of cattle.

The aim of this study was to determine the relative efficiency of factories in disclosing lesions in attested cattle, on the basis of the submission of lesions and their confirmation as bovine TB. The analyses have attempted to control for a broad range of potential confounding factors, including the geographical risk of infection, the bovine TB history of the farms of origin, the animals' characteristics (age, sex and whether they were homebred) and the season of slaughter. The study is based on data relating to lesions submitted and confirmed as bovine TB during 2003 and 2004.

MATERIALS AND METHODS

Databases

The data were obtained from the Centre for Veterinary Epidemiology and Risk Analysis at University College Dublin, Ireland. Three primary databases were used, as follows.

TABLE 1: Numbers of attested animals slaughtered, the percentage of these animals from which at least one lesion was submitted, and the percentage of the latter animals in which bovine tuberculosis was confirmed, with respect to the classes of the various confounding factors and adjusted odds ratios (ORs) with their 95 per cent confidence intervals (CIs) for submission and confirmation

Confounding factor	Class	Total number slaughtered	One or more lesions submitted (%)	Submitted lesions confirmed (%)	Adjusted OR for Submission (95% CI)	Adjusted OR for Confirmation (95% CI)
Age (years)	0-1	51,151	0·09	72·3	1·00 (reference)	1·26 (0·64-2·48)
	1-2	601,116	0·16	61·4	1·39 (1·04-1·87)	1·00 (reference)
	2-3	1,393,962	0·20	60·0	1·74 (1·29-2·33)	1·05 (0·89-1·25)
	3-4	126,715	0·34	62·7	2·91 (2·14-3·95)	1·06 (0·82-1·38)
	4-5	57,018	0·41	66·0	3·64 (2·64-4·99)	1·19 (0·86-1·65)
	5-6	50,294	0·35	70·1	3·10 (2·24-4·30)	1·38 (0·95-2·01)
	6-7	48,058	0·32	72·4	2·78 (1·99-3·88)	1·52 (1·01-2·28)
	7-8	34,994	0·38	69·9	3·31 (2·35-4·64)	1·37 (0·90-2·09)
	≥8	11,679	0·41	79·2	3·47 (2·31-5·22)	2·17 (1·04-4·53)
Sex	Female	854,272	0·22	67·0	1·00 (reference)	1·27 (1·09-1·48)
	Male	1,520,715	0·20	59·1	1·01 (0·94-1·09)	1·00 (reference)
Season	Jan-Mar	548,194	0·22	63·3	1·32 (1·21-1·44)	1·26 (1·05-1·50)
	Apr-Jun	518,067	0·18	61·2	1·00 (reference)	1·11 (0·93-1·33)
	Jul-Sep	634,429	0·20	58·0	1·07 (0·98-1·16)	1·00 (reference)
	Oct-Dec	674,297	0·23	65·1	1·24 (1·14-1·34)	1·36 (1·16-1·59)
DED risk class	1	458,382	0·18	60·8	1·01 (0·92-1·10)	1·04 (0·87-1·26)
	2	728,602	0·18	59·5	1·00 (reference)	1·00 (reference)
	3	650,081	0·22	64·3	1·18 (1·09-1·27)	1·25 (1·06-1·47)
	4	537,922	0·27	63·0	1·27 (1·17-1·37)	1·36 (1·15-1·60)
History (years clear)	0-1	407,796	0·23	63·7	1·19 (1·06-1·35)	1·16 (0·99-1·37)
	1-2	278,048	0·23	63·4	1·19 (1·04-1·36)	1·16 (0·96-1·41)
	2-3	231,880	0·20	63·0	1·08 (0·94-1·24)	1·13 (0·91-1·39)
	3-4	193,260	0·18	63·5	1·00 (reference)	1·22 (0·96-1·55)
	≥4	1,264,003	0·21	60·7	1·15 (1·03-1·28)	1·00 (reference)
Homebred	No	973,851	0·20	63·4	1·10 (1·04-1·17)	1·00 (reference)
	Yes	1,401,136	0·22	61·1	1·00 (reference)	1·02 (0·90-1·17)

DED District Electoral Division

Animal movement Data were available on 3,678,914 cattle slaughtered in 2003 or 2004, including their identification number, birth date, slaughter date and sex, and the herd's identification number.

Tuberculin test results Results were available for all of the tuberculin tests conducted in Ireland after January 1990. All herds are tested at least once annually, but herds with confirmed or suspected bovine TB are tested more frequently. The information derived from this database included each herd's identification number, its locality in terms of its District Electoral Division (DED), the testing date, the number of reactors and the total number of animals tested. These data were used to calculate the level of bovine TB, at animal level, in the DED where each herd was located, on the basis of the number of positive single intradermal comparative tuberculin tests (SICTTs) divided by the total number of SICTTs conducted between 1997 and 2004.

Laboratory results The laboratory database contained 7398 records of examinations conducted on lymph nodes and other materials submitted from animals from attested herds, that is, animals sent to slaughter with an animal identity card, rather than a movement permit, that were submitted to the laboratory after bovine TB had been suspected in the course of factory surveillance. The processing of the samples and the interpretation of the results have been described by Costello and others (1998). Histopathological diagnosis of tuberculosis was based on the presence of granulomatous lymphadenitis associated with areas of caseous necrosis. Lesions were cultured only when the histopathological results were inconclusive. An animal was considered positive if it was positive by histopathology and/or culture. The information used from the laboratory database included each animal's identification number and the laboratory finding.

The data were first validated to remove duplicate records, and to track reasons for missing values. The three databases were then transposed, sorted and merged to combine all the information available. This composite dataset was used to calculate, for each animal, the history of bovine TB on its farm, defined as the number of months during which there had been no evidence of bovine TB before the animal was slaughtered.

Analyses

The data were used to calculate the number of attested animals that were slaughtered, the number of slaughtered animals from which at least one lesion was submitted for further examination, and the number of slaughtered animals from which at least one submitted lesion was confirmed as being positive for bovine TB .

Submission risk A multivariable logistic regression model was developed to calculate the risk of lesion submission for each factory, while adjusting for the other potential confounding factors. Using animal as the unit of interest, the following model was used:

$$\text{Logit } (P[Y=1|F+x]=\mu+F+x_1 \ldots x_6$$

where: $P(Y=1|F+x)$ is the probability that a lesion was submitted for laboratory confirmation from an attested animal at slaughter by factory F, while adjusting for a set of confounders (x); μ is the overall mean; F is the factory (42 classes); x_1 is the sex (two classes: male and female); x_2 is the animal's age (nine classes: 0 0 to one year old, 1 One to two years old . . . 8 Eight years and older); x_3 is the slaughter season (four classes, each being one quarter of a year); x_4 is the length of the clear period of the herd of origin (five classes: 0 Less than one year, 1 One to two years, 2 Two to three years, 3 Three to four years, 4 Four years or longer); x_5 is the DED risk (four classes: very low, low, medium, high); x_6 is whether the animal was homebred or purchased.

The DED risk was based on the quartiles (25 per cent, 50 per cent and 75 per cent) of the reactors per 1000 animals tested. These quartiles were 1·16, 2·52 and 4·58. Ireland is

TABLE 2: Total numbers of attested cattle slaughtered in each factory, the numbers with complete data for confounding factors, the factories' crude and adjusted risks of submitting tensions, and their rankings from lowest to highest rates of submission

	All animals from the attested herds			Animals from the attested herds with complete data for confounding factors				
	Number	Crude submission		Number	Adjusted submission		Crude submission	
Factory	slaughtered	Risk (%)	Rank	slaughtered	Risk (%)	Rank	Risk (%)	Rank
1	206,466	0·22	24	134,311	0·22	24	0·17	21
2	141,927	0·12	12	102,496	0·10	9	0·11	11
3	120,895	0·25	29	81,596	0·29	30	0·24	30
4	153,154	0·11	11	117,939	0·12	13	0·10	10
5	21,754	0·19	18	13,154	0·17	16	0·15	17
6	131,388	0·11	10	107,821	0·10	11	0·11	12
7	160,086	0·24	25	108,558	0·28	29	0·20	26
8	155,984	0·27	31	118,747	0·34	36	0·24	32
9	195,970	0·21	21	116,289	0·23	25	0·17	20
10	200,408	0·58	42	117,713	0·52	41	0·44	41
11	97,497	0·18	16	81,503	0·15	14	0·15	18
12	52,169	0·24	26	31,886	0·23	26	0·18	24
13	135,241	0·27	32	91,811	0·30	31	0·23	29
14	38,514	0·44	39	25,672	0·40	40	0·33	40
15	121,845	0·21	22	85,744	0·22	23	0·16	19
16	111,881	0·42	38	72,041	0·35	37	0·28	35
17	98,878	0·15	13	66,556	0·17	15	0·13	14
18	119,843	0·47	40	66,465	0·36	38	0·32	38
19	110,401	0·28	33	89,247	0·26	28	0·27	34
20	114,476	0·34	36	72,941	0·31	32	0·24	31
21	131,049	0·39	37	82,521	0·40	39	0·33	39
22	25,835	0·24	27	16,351	0·18	17	0·15	16
23	89,873	0·10	9	62,053	0·09	8	0·09	9
24	43,088	0	2	26,731	0	3	0	2
25	114,926	0·30	35	94,216	0·33	34	0·32	37
26	106,359	0·29	34	71,330	0·33	35	0·26	33
27	83,970	0·08	6	50,318	0·10	10	0·08	8
28	48,052	0·53	41	36,579	0·65	42	0·54	42
29	1377	0·22	23	963	0·32	33	0·31	36
30	324	0	1	282	0	2	0	1
31	29,558	0·16	14	21,994	0·19	18	0·15	15
32	16,066	0·21	20	12,266	0·20	19	0·18	25
33	1959	0·05	3	1042	0	1	0	2
34	20,986	0·08	5	16,496	0·07	5	0·07	6
35	105,603	0·19	17	84,095	0·22	22	0·17	22
36	11,921	0·09	8	8,706	0·08	7	0·07	5
37	6285	0·06	4	4816	0·04	4	0·04	4
38	5056	0·26	30	3721	0·21	20	0·21	28
39	38,202	0·17	15	23,607	0·24	27	0·21	27
40	4887	0·25	28	3410	0·12	12	0·12	13
41	41,283	0·09	7	35,576	0·07	6	0·08	7
42	25,321	0·20	19	15,424	0·21	21	0·18	23
Total	3,440,757			2,374,987				
Average		0·22			0·22		0·19	

divided into 3440 DEDs, and animals from 2845 of these were slaughtered during 2003 and 2004.

Confirmation risk A comparable model was used to analyse the effect of factory on the risk of bovine TB being confirmed in the lesions submitted, using animal as the unit of interest. Samples from which *M bovis* was not isolated and no alternative diagnosis was made were considered to be negative, and the sensitivity of the laboratory tests was assumed to be constant. All analyses were made using SAS v8.2 (SAS).

Adjusted submission and confirmation risks were derived from the output of the logistic regression, and the factories were ranked accordingly. The adjusted and unadjusted risks were compared to determine the effect of this adjustment on the estimates of risk and on the ranking of the factories.

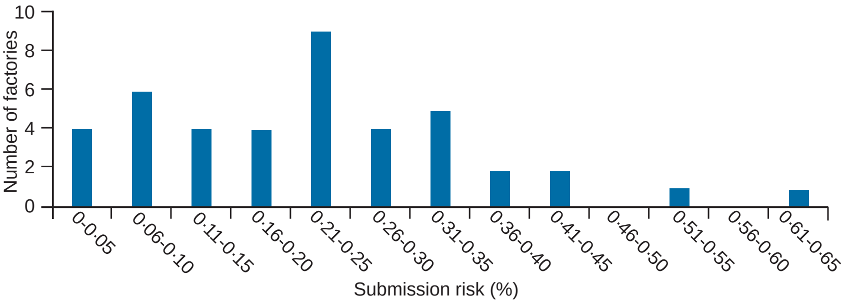

FIG 1: Numbers of factories with different risks of submitting lesions from attested cattle

RESULTS

Descriptive data

Data were available on 3,678,914 cattle, including 3,491,468 (94·9 per cent) slaughtered at one of the 42 export-licensed factories and 3,440,757 from attested herds. In the final multivariable models, 2,374,987 attested animals (64·6 per cent of all the animals slaughtered, and 69·0 per cent of the animals from attested herds) were included, from 84,510 herds in 2845 DEDs. Data on approximately one million potentially eligible animals were not included, either because data were

TABLE 3: Total numbers of attested cattle from which lesions were submitted by each factory, the percentages confirmed positive for bovine tuberculosis, and the crude and adjusted risks of confirmation and their rankings from lowest to highest rates of confirmation

	All animals from the attested herds			Animals from the attested herds with complete data for confounding factors				
	Number	Crude confirmation		Number	Adjusted confirmation		Crude confirmation	
Factory	submitted	Risk (%)	Rank	submitted	Risk (%)	Rank	Risk (%)	Rank
1	353	69·7	26	231	67·2	24	65·8	24
2	145	76·6	32	110	77·5	33	77·3	33
3	259	59·1	10	192	57·2	13	57·3	13
4	146	86·3	37	122	86·4	37	86·1	37
5	35	68·6	23	20	55·0	8	55·0	9
6	128	63·3	17	119	64·2	21	63·9	21
7	321	70·4	28	221	68·2	25	67·9	25
8	366	70·2	27	290	70·3	29	69·3	29
9	306	69·0	24	200	65·5	22	65·5	23
10	953	61·2	14	518	61·8	18	60·4	18
11	142	70·4	29	125	69·0	27	68·0	26
12	109	61·5	15	57	51·3	6	50·9	7
13	326	66·9	21	209	66·3	23	65·1	22
14	151	58·9	9	84	55·1	9	54·8	8
15	204	75·5	31	140	70·5	30	70·0	30
16	344	63·1	16	202	60·6	17	58·9	16
17	140	63·6	19	87	55·7	12	55·2	12
18	479	67·2	22	214	64·0	20	63·1	19
19	280	46·8	4	245	46·6	4	45·7	4
20	350	71·4	30	178	69·8	28	68·5	28
21	413	66·1	20	269	68·8	26	68·4	27
22	54	81·5	34	24	75·4	32	75·0	32
23	80	83·8	35	56	85·8	36	85·7	35
24	1	100·0	38	0				
25	324	59·9	11	297	60·5	16	59·9	17
26	265	61·1	13	186	58·8	15	58·1	14
27	60	63·3	18	41	63·4	19	63·4	20
28	233	34·3	2	196	34·1	2	33·7	2
29	3	100·0	38	3	100·0	38	100·0	38
30	0			0				
31	41	48·8	5	32	47·3	5	46·9	5
32	28	46·4	3	22	41·0	3	40·9	3
33	1	100·0	38	0				
34	15	60·0	12	12	57·8	14	58·3	15
35	173	54·9	6	147	55·4	11	55·1	10
36	10	80·0	33	6	83·3	34	83·3	34
37	2	100·0	38	2	100·0	38	100·0	38
38	12	58·3	8	8	51·3	7	50·0	6
39	59	57·6	7	49	55·2	10	55·1	10
40	8	12·5	1	4	0	1	0	1
41	33	84·8	36	28	85·8	35	85·7	35
42	46	69·6	25	27	70·6	31	70·4	31
Total	7398			4973				
Average		64·4			63·5		63·0	

missing about their birth date or sex (mainly animals born before the animal identification and registration system was fully operational), or because they had not been present in the source herd at the time of the last herd test, or because the attested status of the herd had been misclassified (although these animals were accompanied by an identity card, suggesting an attested herd status, they had been tested either as an inconclusive skin reactor or derived from a herd under bovine TB restriction).

Lesions from 7398 animals from attested herds were submitted for laboratory confirmation. Complete data suitable for the multivariable analyses were available for 4973 of these animals. Lesions from 3088 (62·1 per cent) animals from 2506 herds (on average, 1·23 lesions per herd) were confirmed as being positive for bovine TB; 1451 (29·2 per cent) tested negative and 434 (8·7 per cent) were classified as inconclusive.

Submission risk

Table 1 shows the numbers of animals slaughtered, the numbers and percentages of animals from which at least one lesion was submitted for laboratory examination (by all classes of each potential confounding factor), the numbers of animals in which the lesions were confirmed as being positive for bovine TB, and the adjusted odds ratios (ORs) for submission and confirmation. The odds (risk) of submission increased with age, was equal for females and males, and was highest in October to March and lowest in April to June. The odds of submission were lower among animals that originated from DEDs with a lower proportion of reactors. Compared with herds in which no reactors had been found during the previous four years, the odds of submission was higher among animals from herds with a recent history of bovine TB . Apart from that for age, these ORs were less than 1·5.

The adjusted factory submission risk ranged from 0 to 65 per 10,000, with an average of 22 and a median of 22 (Table 2, Fig 1). After excluding the eight factories that submitted suspected lesions from fewer than 10 animals, the submission risk ranged from seven to 65 per 10,000. The correlation between the adjusted and unadjusted submission risks (based on the data for animals with complete records) was

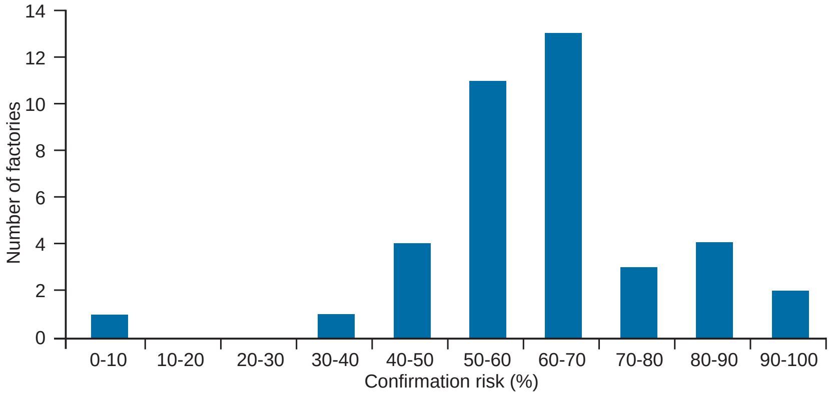

FIG 2: Numbers of factories with different risks of having suspected lesions being confirmed as bovine tuberculosis

0·98, indicating that adjusting for the effects of confounding factors had little effect on the ranking of the factories according to their submission risk. The correlation between the adjusted submission risk and the crude submission risk calculated for all the animals, including animals with incomplete data concerning potentially confounding factors, was 0·94, indicating that the relatively large proportion of animals with incomplete data did not affect the ranking of the factories according to their submission risk.

The numbers of animals slaughtered at each factory are shown in Table 2. Three factories did not submit any lesions for bovine TB confirmation (Table 3), including two that processed only a small number of animals. Table 2 also shows the estimated probabilities of submission per factory based on the total dataset as well as on the dataset of animals with complete information about confounding factors.

Confirmation risk

The overall confirmation risk was 63·5 per cent. Among the 36 factories that submitted at least 10 animals, the confirmation risk varied from 33·7 to 86·1 per cent (Table 3, Fig 2). Neither the adjustment for confounding factors nor the inclusion of records with incomplete information about these factors affected the ranking of the factories. There were very high correlations between the unadjusted and adjusted confirmation risks for the animals with complete information about confounding factors (0·99) and for those without (0·98).

The association between the submission and confirmation risks at each factory was significant when the crude risks were compared ($r=-0·36$, $P<0·05$), but not when the adjusted risks were compared ($r=-0·26$, $P=0·12$).

DISCUSSION

The aim of this study was to compare the efficiency of export-licensed factories in detecting lesions of bovine TB among attested cattle, by comparing their rates of submission of lesions and their rates of confirmation of the disease. Differences could be important, because between 27 and 43 per cent of new herd breakdowns in any one year between 1993 and 2001 were first detected through factory surveillance (O'Keeffe and White 1999; T. Clegg, personal communication). National databases of cattle slaughter, tuberculin testing and laboratory findings were used to make the comparisons.

There were substantial variations between the surveillance efficiency of the 42 factories, in terms of both the risk of submission and of confirmation. The observed factory submission risk ranged from 0 to 58 animals per 10,000 animals slaughtered (Table 2) with an average of 22 per 10,000, and there was a ninefold range in the submission risk after the factories that submitted fewer than 10 animals had been excluded. These results are in broad agreement with the results of Martin and others (2003), who found a sevenfold difference between factories after controlling for year, month and animal type. Similarly, the factory confirmation risk ranged from 33·7 to 86·1 per cent, with an average of 63 per cent. In broad terms, two explanations for these variations are possible: there may be considerable differences between the risk profiles of the cattle slaughtered at each of the factories, and the factories may vary substantially in their efficiency and/or accuracy of detecting lesions, affecting their submission and confirmation risk, respectively. A range of factors, including location and type of animal, are known to affect the infection risk of Irish cattle, and factories often slaughter cattle of a defined type and/or from a relatively well defined geographical area. Through multivariable modelling, a number of known animal- and farm-level confounding factors have been controlled for. However, the variations in the risk profile of the animals among the factories were substantially less than expected, given the close agreement between the crude and adjusted estimates of factory risk, and it can therefore be concluded that animal- and farm-related factors did not contribute significantly to the variations in factory-level submission and confirmation risks observed. By exclusion, therefore, factory-level factors would have accounted for much of the variation in factory efficiency. Collins (1997) suggested that variations in factory surveillance efficiency may be due to factory-related circumstances, for example, line speed and light intensity, and/or to factors related to the veterinary inspector, for example, their experience, interest, motivation and workload. These possible factors are being considered in both industry and government, and further research may be warranted. It will be important to continue to monitor the submission and confirmation risks in Irish factories to assess the efficacy of any changes that are introduced.

A confirmation risk of 100 per cent is neither achievable nor desirable. Granulomas due to bovine TB cannot be distinguished from non-tuberculous granulomas, such as those due to infection with *Actinobacillus lignieresii,* on the basis of visual inspection, incision and palpation alone, and further laboratory examination is therefore needed. Inspectors should be encouraged to maximise sensitivity, rather than specificity, to maximise the number of bovine TB lesions detected, and thus the efficiency of factory surveillance in identifying bovine TB-infected herds. In the Australian programme, meat inspectors are encouraged to submit all granulomas, rather than just those that appear to be bovine TB granulomas, to the laboratory for examination by histopathology and/or culture (Radunz 2006). In Ireland, there is substantial variation between the confirmation risks of different factories, indicating that the practices applied in submitting lesions are not uniform. As would be expected, there was a small negative correlation between the submission risk and the confirmation risk; as the number of submissions increased, the percentage of the lesions that were confirmed as bovine TB decreased.

The exclusion of animals with incomplete data reduced the average crude risk of submission from 0·22 per cent to 0·19 per cent (Table 2). Animals were excluded mainly because of missing birth dates; most of them were probably older animals, because the animal identification system was not fully operational before 1996. The inspection of older animals had a higher probability of disclosing lesions of bovine TB (Table 1), probably because they had been at risk of exposure for longer and had a greater chance of having completed the incubation period; hence the lower crude submission risks when animals with incomplete information were excluded. The exclusion of data on these animals did not change the ranking of the factories with respect to their crude submission risk.

The submission and confirmation risks both varied considerably, as a result of a range of factors including the animal's age, sex, the season of slaughter, and whether it was homebred, and the location and past bovine TB history of its farm of origin. These findings are consistent with the results on the influence of location by O'Keeffe and others (2002), on past bovine TB history by Olea-Popelka (2002) and Olea-Popelka and others (2003), and on the age of the animals by Martin and others (2002), all in the Irish setting. The more reactors found in the DED from which the animal came, the higher were the odds of a suspect lesion being submitted (DED risk class). Animals from herds in which a reactor had been detected in the previous two years also had higher odds of a suspect lesion being submitted. The seasonal pattern in laboratory submissions was similar to the pattern found by Martin and others (2003), which may be related to the seasonal exposure between badgers and cattle, as suggested by Martin and others (2002). During winter, when food resources are less plentiful, it is possible that badgers may more often gain access to cattle housing and forage in cattle troughs, with the potential to increase exposure of cattle to infected badgers (Garnett and others 2002).

Field surveillance is the primary method of detecting bovine TB infections in Irish herds. All Irish cattle are tested by the SICTT at least once a year, and the majority of new herd breakdowns are detected by this annual procedure. As part of the current programme, factory surveillance makes it possible to detect infection during the period between annual tests, thereby reducing the magnitude of the herd problem and the risk of the disease spreading between herds. No further reactors are found at subsequent SICCTs in approximately 80 per cent of herd breakdowns first detected during factory surveillance (F. J. Olea-Popelka, P. W. White, E. Costello, G. McGrath, J. D. Collins, J. O'Keeffe, D. F. Keltan, O. Berke, S. J. More, S. W. Martin, unpublished observations). In many cases it is suspected that the infected animals may have been infected for a long time but were not reactive to the annual SICTT. They could presumably have become infectious, with the potential to spread bovine TB within the herd and between herds at some time in the future. Furthermore, from the perspective of food safety, factory surveillance prevents the carcases of animals with generalised bovine TB from entering the food chain. Carcases of animals with localised or suspected lesions can enter the food chain without posing any known threat to food safety (European Food Safety Authority 2003).

Improved factory surveillance would contribute to national efforts to control bovine TB. The identification of infected herds before the scheduled annual or other tuberculin test would help to minimise the size of major breakdowns in an index herd and the spread of infection from an index herd to contiguous herds.

During 2003 and 2004, there were substantial differences between the surveillance efficiencies of Irish factories, as measured by their risks of submitting lesions and having them confirmed. These differences were unlikely to have been attributable to differences in the risk profile of the cattle slaughtered at each factory. They are more likely to have been due to inherent differences between the factories. Although factory surveillance is not the primary method for detecting bovine TB infections in Irish herds, it plays an important role in the early detection of infected herds and in the detection of animals that are not reactive to the tuberculin test. Improvements in the efficiency of factory surveillance would improve bovine TB disease control and help to ensure that measures to safeguard food safety are enforced.

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Quantification of the relative efficiency of factory surveillance in the disclosure of tuberculosis lesions in attested Irish cattle

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